Union of So. Africa
No. 19

SEP 1955
LIBRARY
POFI
FISH & WILDLIFE
SERVICE

No. 19

UNION OF SOUTH AFRICA

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES

INVESTIGATIONAL REPORT No. 19

THE SOUTH AFRICAN PILCHARD

(Sardinops ocellata)

THE DEVELOPMENT OF THE SNOEK

(Thyrsites atun)

A FISH PREDATOR OF THE PILCHARD

BY

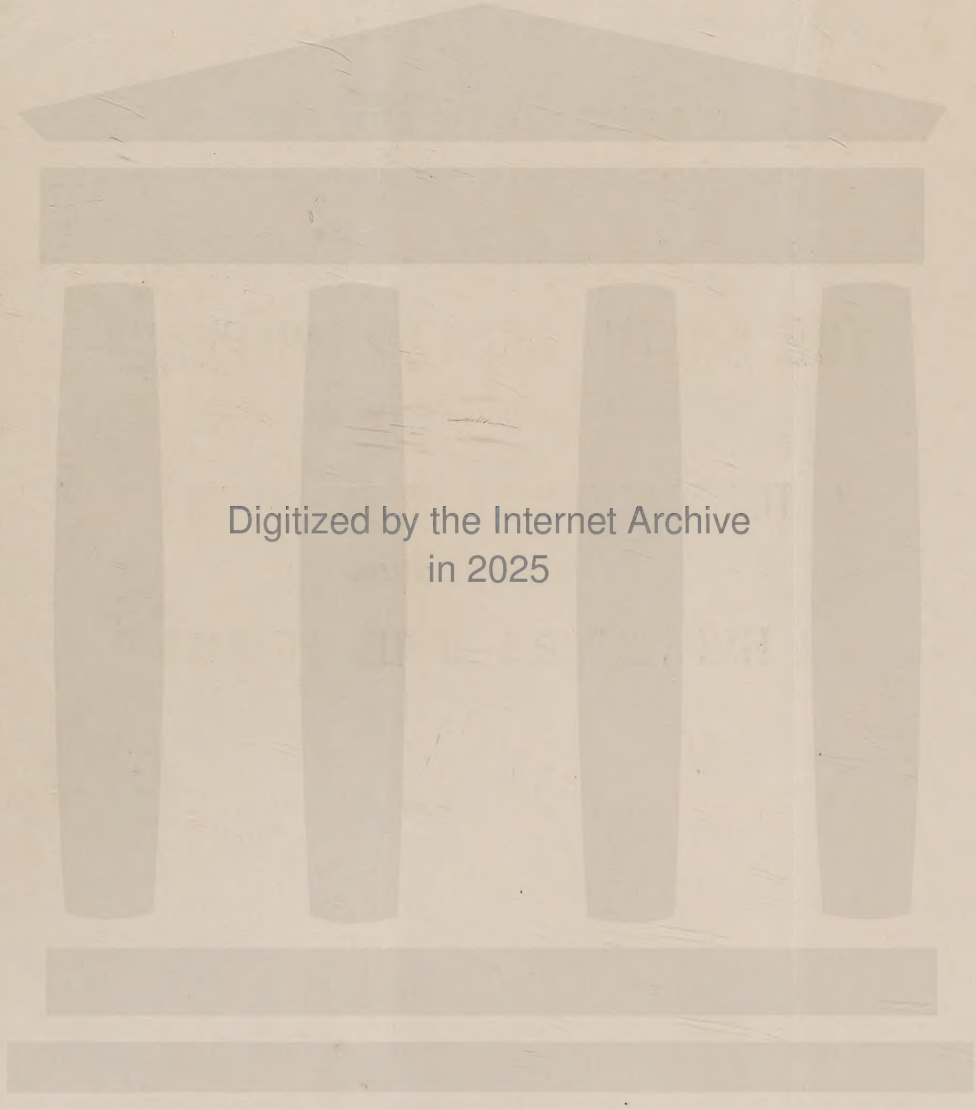
B. v. D. de JAGER, M.Sc.

(Professional Officer)

THE GOVERNMENT PRINTER, PRETORIA

1955

G.P.-S.117913—1954-5—200.



Digitized by the Internet Archive
in 2025

https://archive.org/details/investigational-report-sfri-za_1955_19

Reprint from "Commerce & Industry". MAY, 1955

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES

INVESTIGATIONAL REPORT No. 19

THE SOUTH AFRICAN PILCHARD

(Sardinops ocellata)

THE DEVELOPMENT OF THE SNOEK

(Thyrsites atun)

A FISH PREDATOR OF THE PILCHARD

BY

B. v. D. de JAGER, M.Sc.

(Professional Officer)

Contents.

	PAGE
1. Summary	3
2. Introduction	3
3. Method	3
4. Embryological Development	4
(*a*) Eggs	4
(*b*) Blastodisc	4
(*c*) Cleavage	5
(*d*) Blastodermal cap	5
(*e*) Hatching	6
5. Larval Development	7
6. Note on Migration	8
7. Acknowledgments	9
8. References	11

1. SUMMARY.

This paper is one of a series in connection with the life history of the South African pilchard *Sardinops ocellata* (Pappe), and deals with the developmental stages of the snoek *Thyrsites atun* (Euphrasen), which is an important predator of the pilchard and maasbanker *Trachurus trachurus* (Linné).

Results of tagging carried out in 1934 are used as further evidence for a theory on the migration of the snoek.

Snoek eggs were artificially fertilized and their development was studied. A series of drawings was made at successive stages of the development of the eggs and larvae.

A description is given of various methods used to keep the eggs alive and rear the early larval stages.

Droplets of human blood were found to be the best food for the developing larvae after absorption of the yolk sac. Larvae were kept alive for a period of 9 days after hatching. The death of the larvae at this stage is considered to be due mainly to the inadequate nutritive value of human blood.

2. INTRODUCTION.

The artificial fertizilation of the South African stockfish or hake, *Merluccius capensis* (Castelnau), was successfully carried out for the first time in R.S. *Africana.* The development of the eggs and early larval stages was studied and described as a contribution to our knowledge of the early life histories of South African fishes. (Matthews and De Jager, 1950.)

Early in 1950, shortly after the arrival in Cape Town of R.S. *Africana II,* the Division of Fisheries began an extensive pilchard research programme. In the execution of this programme the three research vessels of the Division worked a routine network of stations offshore and inshore in the neighbourhood of the commercial fishing area of St. Helena Bay. During the course of these investigations in October, 1950, two snoek *Thyrsites atun,* were caught in the trawl by R.S. *Africana II.* On examination the two fish were found to be a male and a female, both in ripe and running condition. As far as is known this was the first recorded instance of the finding in South African waters of a sexually ripe and running male snoek and a similarly conditioned female snoek at one and the same time. Full use of the fortuitous occurrence of this rare event was made to carry out successful artificial fertilization. Davies (1954) lists the snoek as an important predator of the pilchard and the maasbanker. This successful fertilization of the snoek is therefore important not only because it sheds light on the early development of a fish of very considerable commercial importance, but also because the snoek is one of the chief fish predators of the pilchard, *Sardinops ocellata.*

3. METHOD.

Approximately 3,000 ripe ova were removed from the ovaries of the female snoek by means of pipettes with large orifices and were released in a round glass vessel containing fresh sea-water. To this a few c.c. of fluid from the running milt of the male fish were added, and the mixture gently but well stirred with a glass rod. The vessel containing the eggs was kept on a gimbal table to minimise damage to the eggs by the movement of the ship. Fertilization took place and the eggs floated to the surface. The sea-water in which the eggs were kept became foul rapidly and had to be renewed frequently. The siphoning-out of the old water and its replacement with fresh sea-water had to be very carefully carried out to avoid damage to the delicate eggs. Care was taken to keep the temperature of the water as constant as possible.

The movement of the ship made it impossible to make drawings of developing eggs under the microscope. Small numbers of eggs were therefore taken out at hourly intervals and preserved in 2 per cent neutral formalin for detailed study ashore. As soon as the ship reached port the glass vessels containing the developing eggs were transported to the shore laboratories where various methods of treatment of the fertilized ova were tried during the period of development.

Among the methods used were the following:—

(*a*) Approximately half the fertilized ova were transferred to a glass vessel fitted with a constant-level siphon and supplied with running sea-water from a reservoir placed at a higher level. In this manner the danger of damaging the delicate eggs by air bubbles from an external supply of air was eliminated. In the earlier work with stockfish ova (loc. cit.) this procedure was found to be the most successful of all the methods tried.

(*b*) Smaller numbers of eggs were placed in deep glass beakers half-filled with fresh sea-water and these were floated in running sea-water. As soon as the sea-water showed signs of deterioration it was siphoned off by means of a glass funnel, the mouth of which was covered with fine silk. Fresh sea-water of the same temperature was then carefully added. Dead ova and larvae were removed from the containers at regular intervals. After hatching, the larvae were transferred to similar beakers floating in sea-water.

It was found that method (*b*) was more successful than method (*a*). The reason for this probably lies in the fact that the numbers of eggs in any one beaker used in method (*b*) were small, and therefore the rate of deterioration of the sea-water in which they were floating was very much slower than was the case with the greater number of ova in the same volume of water in method (*a*). Also in method (*a*) bacteria which had a harmful effect on the eggs and larvae, were being continuously introduced in the siphoning water, whereas in method (*b*) the rate of introduction of these bacteria was slower.

The rearing of larvae under artificial conditions beyond the critical period, which extends from the time the yolk sac is absorbed until the larvae start to feed voluntarily, has always been very difficult. In the case of the stockfish, Matthews and De Jager (1950) found that the larvae survived for only 2½ days after hatching. Various feeding substances were tried in rearing snoek larvae after the absorption of the yolk sac. Larva were fed on:—

(i) nauplius stages of the brine shrimp, *Artemia salina;*

(ii) sea-water containing various diatoms;

(iii) minced beef liver pressed through bolting cloth;

(iv) droplets of human blood.

The first two foods were unsuccessful. Beef liver was successful to a certain degree but fouled the water very rapidly. Any manipulation to clean the water, however carefully executed, increased the rate of mortality of the larvae. Feeding with droplets of human blood proved to be the most successful. As soon as a droplet sank to the bottom of the beaker, larvae were seen to feed on it. Human blood was not tried with the rearing of stockfish larvae which, as has been mentioned, survived only 2½ days after hatching. Snoek larvae were kept alive on human blood for 9 days after hatching. The snoek larvae were, however, much livelier after hatching than the stockfish larvae.

Living eggs were withdrawn from the beakers at hourly intervals and drawings were made at successive stages of development. It was not possible to draw living larvae due to their excessive movements and consequently they were fixed by means of diluted formalin and later sketched.

The average temperature of the sea-water throughout the embryological and larval development was 18·5° C. The surface temperature of the water in the area where the two snoek were caught was *circa* 14·0° C. It is likely that the rate of development of the eggs would have been slower at the lower temperature. It was observed that eggs kept at a higher temperature in a watch glass under a lamp developed much faster than eggs kept at 18·5° C.

4. EMBRYOLOGICAL DEVELOPMENT.

(*a*) Eggs.

The eggs of snoek are pelagic and are small, spherical, and transparent in appearance. They contain a single oil globule. The average diameter of fertilized eggs is 0·99 mm. and that of the oil globule 0·26 mm., whilst the unfertilized egg measures 1·00 mm. with an oil globule of 0·25 mm. diameter. Gilchrist (1916) gave measurements for snoek eggs as follows: 0·80—0·84 mm. for the egg diameter and 0·21—0·25 mm. for the oil globule, but he did not state whether these measurements referred to fertilized or unfertilized eggs. The yolk has a granular appearance and the perivitelline space is small. The egg membrane is thin and has an irregularly cracked surface resembling cell structure (see Plate I, Fig. 1).

(*b*) Blastodisc.

The thin, almost imperceptible, layer of protoplasm enveloping the yolk, accumulates almost immediately after fertilization at the animal pole of the egg. This accumulation of protoplasm develops into the blastodisc. The protoplasm is now slightly whitish in colour. Ryder (1884) and Budd (1940) described the streaming motion of protoplasm towards the animal pole of the eggs of various fishes to form the blastodisc. This streaming motion which occurs in the eggs of different species was not observed in snoek eggs.

The slightly irregular blastodisc formed as a result of redistribution of protoplasm appears as a rounded cap at the animal pole and is completed in about one hour after fertilization. A thin layer of protoplasm spreads from the edges of the completed blastodisc and envelops the entire yolk sphere. The slightly concave edge of die blastodisc presses against the yolk sphere which becomes slightly flattened. The distortion caused by this pressure renders the perivitelline space more conspicuous (see Plate I, Fig 2).

(c) Cleavage.

Cleavage and the formation of the two-cell stage occurs two hours after fertilization and is preceded by the lengthening of the blastodisc. Cleavage is brought about by a dividing furrow which does not cut right through the blastodisc but leaves a thin connexion of protoplasm at the edges of the two blastomeres. This protoplasm is continuous with the thin layer of protoplasm enveloping the surface of the yolk sphere. The edges of the blastomeres are rougher than those of the blastodisc. Cleavage does not occur simultaneously in all eggs but the individual cleavages take place approximately at hourly intervals.

The second cleavage occurs about an hour after the first and is effected by means of another dividing furrow which is perpendicular to the first. The four blastomeres formed are not equal in size, the outer two being bigger than the inner two. Approximately three hours after fertilization the third cleavage takes place. The eight blastomeres formed are arranged in two rows of four each. The blastomeres vary considerably in shape and size. The fourth cleavage occurs at about four hours after fertilization. The sixteen cells thus formed appear as a single layer of cells almost circular in shape lying adjacent to the yolk. The next cleavage forms a blastoderm with two layers of cells in the central region.

As previously stated, the cleavage furrows do not cut right through the blastodisc but leave a thin layer of protoplasm joining the cells at their bases next to the yolk. This thin layer of protoplasm at the surface of the yolk becomes concentrated at the periphery of the blastoderm to form a somewhat flattened ridge. [This peripheral protoplasmic ridge was called the periblast by Agassiz and Whitman (1885).] Seven cleavages of the blastoderm occur within 6–7 hours after fertilization. The cells are now much smaller than previously but they are still irregularly shaped (see Plate II, Fig. 7).

(d) Blastodermal Cap.

The stages occurring subsequent to the seventh cleavage are not easily followed. However, their occurrence can be seen by an increase in the number of cells and the formation of a well-rounded, dome-shaped blastodermal cap, which closely resembles a blastodisc. The very small cells are now more regular in shape. The blastodermal cap is well formed about eleven hours after fertilization. After the completion of the blastodermal cap the segmentation cavity becomes evident at approximately 14 hours after fertilization. The cellular walls of this cavity are quite distinct when viewed from the side. When the egg is viewed from above, however, the rim of the blastodermal cap adjacent to the yolk is not as translucent as the thinner roof of the segmentation cavity. The latter appears as a lighter area surrounded by a denser ring of protoplasm. With the enlargement of the segmentation cavity, the central portion of the blastodermal cap becomes thinner and a well-marked groove shows the actual area of the germ ring. After the appearance of the germ ring, the embryonic shield starts to form and develops into a broad area of cells. A thickening of the median line of this area of cells makes it possible to distinguish the general outline of the very early embryo. The germ ring at the anterior end of the embryonic shield now begins to grow over the yolk sphere towards the equatorial position. As the germ ring advances past the equatorial region, constriction of the yolk sphere is evident at about 24 hours after fertilization. The embryo has lengthened considerably and the blastopore is, as yet, not closed. After the closure of the blastopore at about 25 hours after fertilization, gastrulation is completed.

Approximately 27 hours after fertilization the head of the embryo is well formed, and the eyes, not yet containing pupils, can be distinguished. The developing notochord as well as twelve somites can also be seen. The caudal part of the body now lengthens quickly with the addition of somites and the embryo now encircles a major portion of the large yolk sac, upon which very faint pigment cells are sparsely scattered.

At about 37 hours after fertilization the head of the embryo shows further development, but pupils in the eyes have not yet developed. The body has lengthened considerably and contains a large number of somites. At this stage the heart is formed. At approximately 41 hours after fertilization the heart starts beating. At about 46

hours the tail, now encircling most of the yolk sac, loosens its posterior part from the yolk sac. The development of the brain is well advanced and the neural canal, the "anlage" of the nervous system, can readily be observed. Melanophores are distributed dorso-laterally from the head towards the posterior part of the body. The pupils in the eyes are now developed. The posterior portion of the alimentary canal as well as the first signs of the developing internal ears and the pectoral fins now appearing as rounded folds, can be distinguished (see Pate III, Fig. 12).

(e) Hatching.

From the above stage of development to the time of hatching no major changes are observed in the embryo, apart from the enlarging of the whole body and the organs already developed. The melanophores also become more pronounced. The tail is now even more detached from the yolk than before, and rapid, twitching movements

TABLE I.

EMBRYOLOGICAL DEVELOPMENT OF THE SNOEK. EGGS KEPT AT AVERAGE TEMPERATURE OF 18·5° C.

Hours after Fertilization.	Developmental Stage.	Remarks.
1	Blastodisc.....	Perivitelline space evident. Eggs float at surface.
2	Two blastomeres.....	Blastomeres protrude well from yolk sphere.
3	4–8 cell stage.....	
4	16–32 cell stage.....	Successive cleavages rhythmical.
5	64–128 cell stage.....	
6	Blastodermal cap forming.....	Cells very small.
11	Blastodermal cap well-formed...	Rounded lenticular dome.
14	Segmentation cavity and early germ ring..	Germ ring starts centrifugal growth.
15	Embryonic shield.....	Germ ring approaching equatorial position.
24	Early embryo.....	Germ ring beyond equatorial position. Blastopore almost closed.
25	Completion of gastrulation.....	Blastopore closed.
26	6 Somite stage.....	Eyes contain no pupils.
27	12 Somite stage.....	Developing notochord clearly visible.
29	36 Somite stage.....	Embryo encircles major portion of yolk sac.
37	Heart formed.....	Tail coming free from yolk sac.
41	Heart starts beating.....	
46	Advanced stage of embryonic development	Eyes contain pupils. Brain well advanced. Developing internal ears and pectoral fins visible. Distribution of melanophores easily distinguishable. Eggs now float just below surface of water.
49	Hatching starts.....	Vigorous tail and body movements rupture egg shell.
51	General hatching in all containers.....	Egg capsules sink to bottom upon hatching.

occur from time to time. These tail movements, together with the wriggling movements of the body and head, rupture the egg shell. Further movements enable the embryo to liberate itself about half an hour later. The egg capsule sinks to the bottom of the beaker. Hatching starts at approximately 49 hours after fertilization. At about 51 hours after fertilization hatching is at a peak.

Table I summarizes the development of the embryo up to the stage of hatching, and shows the relation between the major changes which occur, together with the times after fertilization at which these changes take place.

5. LARVAL DEVELOPMENT.

The newly-hatched larvae float helplessly upside down at the surface of the sea-water. This is due to the presence of the yolk sac and the oil globule. The larvae are able to swim short distances by means of tail movements but when these movements stop, the larvae return to the surface.

The average length of the larvae one hour after hatching is 2·1 mm. (see Plate IV, Fig. 13). The yolk sac containing the oil globule in a postero-ventral position measures 0·92 mm. in length, 0·60 mm. in width, and 0·60 mm. in depth. The anterior portion of the larva is strongly curved about the ovoid yolk sac. The head does not extend anterior to the yolk sac into which it is strongly deflected. The antero-dorsal profile of the head is rounded and there is no indication of a mouth or jaws. The body tapers posteriorly and the melanophores are dorsally distributed in concentrations from behind the eyes towards the anal region. Two such concentrations are distributed ventrally in the posterior part of the body. The yolk sac extends from past the snout to the rectum which latter is situated in the central part of the body. The fin folds are continuous, the dorsal fold arising just behind the head and is continuous about the posterior end of the trunk, extending anteriorly as a ventral fin fold round the yolk sac as far as the anus. The internal ear is clearly visible and the pectoral fins are larger than hitherto.

No major changes are apparent five hours after hatching except that the body has straightened somewhat, the yolk sac has become slightly smaller due to absorption, and the rectum is seen as a straight tube above and behind the yolk sac. The melanophores are distributed in seven main concentrations in the body. The head extends anteriorly to the yolk sac. (See Plate IV, Fig 14.)

When the larva is one day old it has a total length of 2·9 mm. The yolk sac has become elongated and shallower and now measures 0·99 mm. in length, 0·30 mm. in depth, and 0·50 mm. in width. Now that the yolk sac area has become smaller, the larva takes up a position just below the surface of the water and becomes progressively more active. There is as yet no sign of a developing stomodaeum. The dorsal and ventral fin folds are of about equal depth. The notochord extends from the posterior portion of the brain to the end of the body. It is not curved in the caudal region where the developing ceratotrichia, or larval rays are beginning to appear as supports of the fin fold. The two-chambered heart can readily be seen (See Plate IV, Fig. 15).

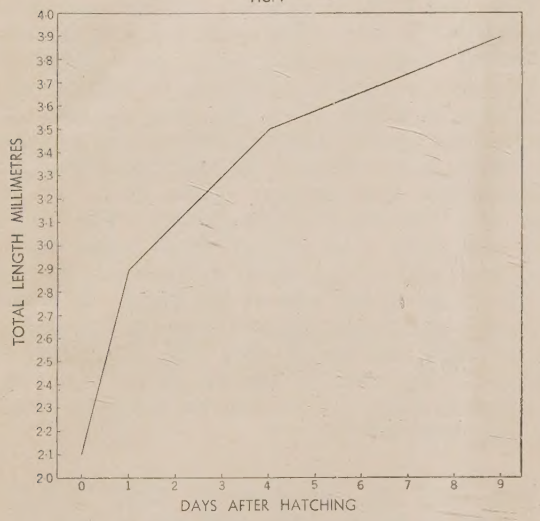
Two days after hatching the larva measures 3·1 mm. in length. The yolk sac is now very small, but the head, eyes, heart, gut, pectoral fins and internal ears are very well developed. There are four main concentrations of melanophores, two in the dorsal fin fold, one posteriorly in the ventral fin fold and another is situated just anterior to the pectoral fin. A small depression in the profile of the head gives evidence of a developing stomodaeum. The larvae are now approaching the critical stage when voluntary feeding must start after the total absorption of the yolk sac, at approximately 3–4 days after hatching (see Plate V, Fig. 16).

Four days after hatching the larva has a total length of 3·5 mm. The mouth and jaws are clearly visible at this stage. The larval fin rays at the tip of the tail are now more distinct. Larvae now float with their heads in a downward position. Movements are much more extensive and are aided by caudal and pectoral fin movements. Two main concentrations of melanophores are present at this stage, one in the dorsal fin fold and one in the ventral fin fold. The marginal pigmentation of the eyes now begins (see Plate V. Fig. 17).

Nine days after hatching the larva has a total length of 3·9 mm. The eyes are heavily pigmented and the jaws are strongly developed. Larvae appear to be undernourished and their swimming movements are jerky and irregular. It is evident that human blood does not supply

sufficient nourishment to keep the larvae alive. On the tenth day all the remaining larvae died (see Plate V, Fig. 18).

FIG. 1



GROWTH OF LARVAE

Figure 1 shows that the snoek larvae grow very quickly when they are dependent on the yolk sac for their food supply. After the absorption of the yolk sac growth is much slower but the larvae show a steady increase in total length. It was observed by Orcutt (1950) on the larval starry flounder (*Platichthys stellatus*), and by Miller (1952) on the pacific sardine (*Sardinops caerulea*), that larvae decrease in total length a few days after the absorption of the yolk sac. This decrease is probably due to lack of nutritive food. Although these workers tried numerous foodstuffs they were unsuccessful and they concluded that their food was not sufficient to keep the larvae alive.

It is the author's experience, however, that snoek larvae do not decrease in size after the absorption of the yolk sac but continue to grow at a much slower rate once this has taken place. It would appear that although a diet of human blood is adequate to allow slow growth of the larvae after absorption of the yolk sac, it is not sufficiently nutritive to maintain life for a period longer than 9 days after hatching.

6. NOTE ON MIGRATION.

On the west coast of the Union and South West Africa snoek are caught at different times of the year. In South West African waters the snoek season is at its height during November, December and January. At the start of the South West African snoek season the fish are usually in poor condition and are sexually inactive. Towards the end of the season, however, there is a marked improvement in the condition of the fish and the gonads become more developed and active. In the seas around St. Helena Bay and the Cape Peninsula the snoek season usually reaches a peak during May, June and July. During this period the fish are in very good condition and they are sexually active and ripe.

The fact that snoek appear at different times along the coasts of the Union and South West Africa has led to various theories regarding the migration of this species. In a recent investigational report of this Division, Davies (1954) explains shortly the migration of snoek as follows: The sexually immature fish caught during the early summer months in South West African waters condition themselves by feeding on pilchards during the later part of the season. At the end of summer a migration in a southerly direction takes place and the fish are caught during the winter season in the commercial fishing areas of St. Helena Bay and off the Cape Peninsula. It is presumed that at the end of the fishing season at the Cape, the snoek move in a westerly direction towards deeper water where spawning probably takes place. After completion of spawning activities a northerly return migration takes place offshore in deeper water and the fish return to South West African waters. When the snoek are again observed in this area they are in poor condition and show signs of having recently spawned. This appears to be a reasonable explanation of the migration of the snoek, and some scientific evidence in support of this theory exists.

In 1934 snoek were tagged off the coast of South West Africa (Marchand, 1934). Table II gives full details of the tagged snoek which were later recovered.

A total of 17 out of 3,755 tagged snoek was recaptured. The position of recapture was south of the position of tagging in every case. This would seem to be proof that snoek migrate southwards from off the South West African coast to the region off the west and south coasts of the Union of South Africa.

TABLE II.

(SEE FIG. 2.—MIGRATION OF SNOEK).

Tag No.	Date of Tagging.	Position Tagged.	Date of Recovery.	Position Recovered.
1968	19/11/34	Walvis Bay.....	26/3/35	Sandfish Harbour.
2615	23/11/34	Pelican Point.....	13/4/35	Port Nolloth.
2317	23/11/34	Pelican Point.....	15/4/35	Shell Bay, St. Helena Bay.
3102	27/11/34	South of Pelican Point.....	25/4/35	South of Conception Bay.
3626	29/11/34	45 miles north of Pelican Point..	14/5/35	3-4 miles west of Paternoster.
1789	16/11/34	Pelican Point.....	4/6/35	Thorn Bay.
4033	29/11/34	45 miles north of Pelican Point..	17/6/35	St. Helena Bay.
2657	23/11/34	Pelican Point.....	8/1/36	Cape Point.
2267	23/11/34	Pelican Point.....	13/1/36	Conception Bay.
3888	29/11/34	45 miles north of Pelican Point..	16/5/36	10 miles west of Cape St. Martin.
2987	29/11/34	45 miles north of Pelican Point..	7/6/36	Buffels Bay, Cape Point.
4439	5/12/34	South of Sandfish Harbour.....	12/6/36	7 miles west of Camps Bay.
1818	16/11/34	Pelican Point.....	19/3/37	Roman Rock, False Bay.
2699	23/11/34	Pelican Point.....	26/4/37	Bullnose, False Bay.
1595	16/11/34	Pelican Point.....	4/5/37	Donkin Bay.
2708	23/11/34	Pelican Point.....	19/5/38	St. Helena Bay.
3524	29/11/34	45 miles north of Pelican Point..	23/6/38	Robben Island.

It can be seen from Table II that a fish tagged off Pelican Point (Tag No. 2317) travelled a minimum distance of 630 miles in 144 days before it was recaptured off St. Helena Bay. This corresponds to a minimum speed of over 4 miles a day.

Table II also shows that snoek tagged on the same day were subsequently recaptured progressively farther south with the lapse of time. For example, two fish tagged at Pelican Point on 23rd November, 1934, were caught on 13th April, 1935, and 15th April, 1935, at Port Nolloth and Saldanha Bay respectively. It is also interesting to note that a snoek tagged off Pelican Point, South West Africa, on 23rd November, 1934, was caught in the same area nearly fourteen months later. It is unlikely that this fish remained in South West African waters during this period and it probably followed the same southerly movements as the other fish. It is possible that this fish completed a southerly and a return northerly migration, i.e., from South West African waters to the Cape and back to South West Africa.

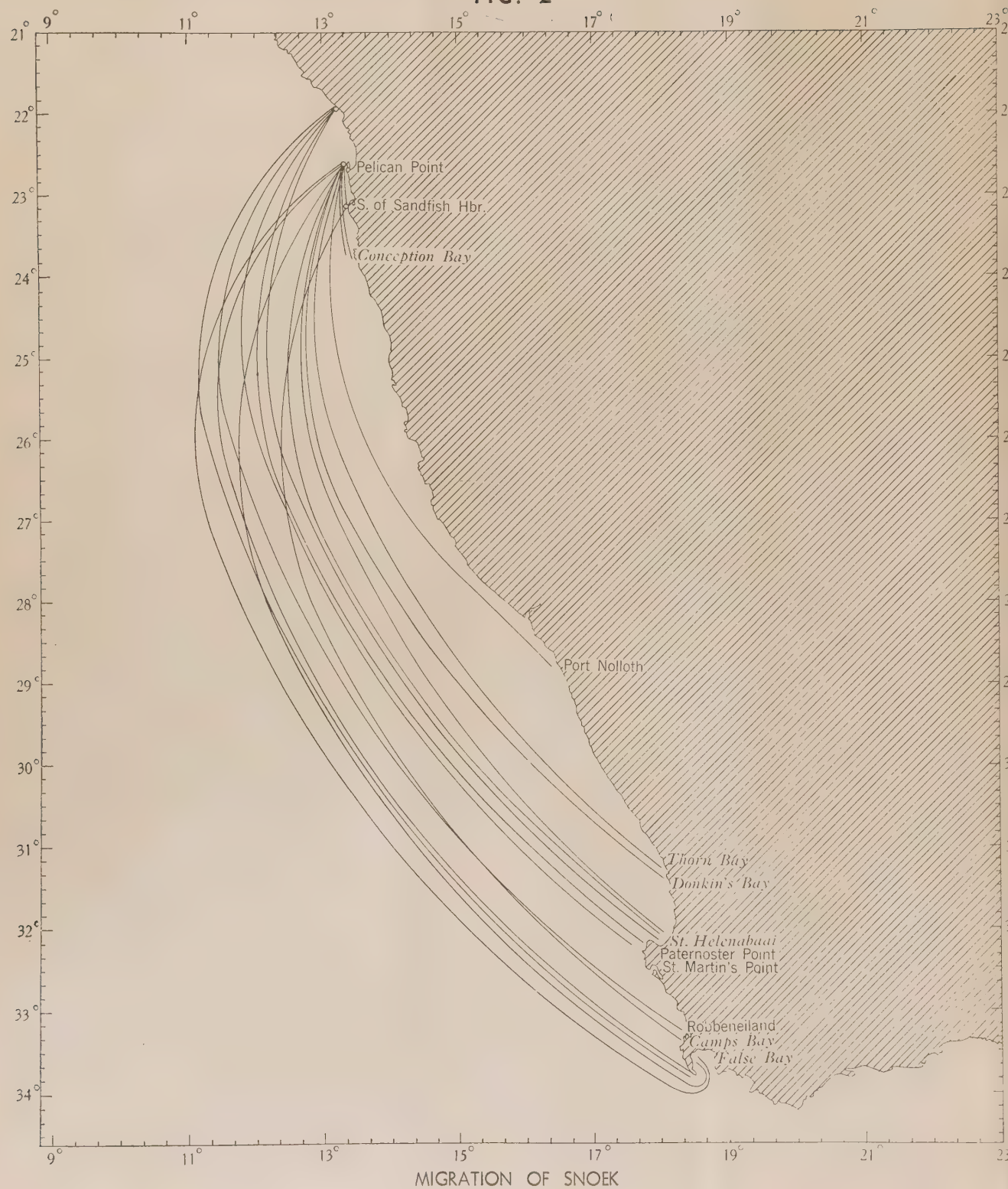
The gonads of snoek caught towards the end of the fishing season at the Cape are usually in a ripe condition. This is an indication of the imminence of spawning. The capture of two ripe and running snoek in October, 1950, on the trawling grounds 45 miles north-west of Cape Town, indicates that this species probably spawns in offshore waters. No direct evidence exists for the return journey from the Cape to South West African waters, but there are some few facts indirectly indicative of such a movement, viz. spent snoek are often caught to the north up to 70 miles west of St. Helena Bay in October and November, whilst off South West Africa the snoek caught in the beginning of the season show that they have either recently spawned or that they have recovered condition but are still sexually inactive.

It is of interest to note that fish tagged as early as 29th November, 1934, off South West Africa were recaptured only on 23rd June, 1938, in the Cape Peninsula area. This shows that tagging, when carefully carried out, has no detrimental effect on the fish.

7. ACKNOWLEDGMENTS.

Acknowledgment is gratefully made to the officers and men of R.S. *Africana II* who provided the material for this work. For critical reading of the manuscript and helpful advice I am indebted to the following: Dr. J. M. Marchand, Director of Fisheries, Mr. C. G. du Plessis, Assistant Director of Fisheries, Dr. A. J. Clowes, Senior Hydrologist and Mr. D. H. Davies, Senior Biologist. The author is particularly grateful to Mr. Davies for considerable help in watching and sketching the various developmental changes.

FIG. 2



MIGRATION OF SNOEK

8. REFERENCES.

BUDD, P. L., 1940.—*Development of the Eggs and Larvae of Six California Fishes.* State of Calif. Div. Fish and Game, Fish. Bull., 56. pp. 1–53. Sacramento.

CUNNINGHAM, J. T., 1894.—*Experiments on the Rearing of Fish Larvae in the Season of* 1894. Journ. Mar. Biol. Assoc. of U.K., III, No. 3, pp. 206–207. Plymouth.

DANNEVIG, G. M., 1908.—*Apparatus and Methods employed at the Marine Fish Hatchery at Flödevig, Norway.* Bull. Bur. of Fish. U.S.A., XXVIII, Pts. I and II, pp. 799–810. Washington.

DAVIES, D. H., 1954.—*The South African Pilchard (Sardinops ocellata)—Development, Occurrence and Distribution of Eggs and Larvae,* 1950–51. Department of Commerce and Industries, Division of Fisheries, Invest. Rep. No. 15, pp. 1–26. Pretoria.

FRY, D. H., 1936.—*A Description of the Eggs and Larvae of the Pacific Mackerel.* Calif. Fish and Game, 22, No. 1, pp. 28–30. Sacramento.

GILCHRIST, J. D. F., 1904.—*The Development of South African Fishes, Pt. I.* Mar. Invest. in S.A., II, pp. 181–201. Cape Town.

GILCHRIST, J. D. F., 1905.—*The Development of South African Fishes, Pt. II.* Mar. Invest. in S.A., III, pp. 131–167. Cape Town.

GILCHRIST, J. D. F., 1916.—*Eggs and Larvae of Cape Fishes.* Mar. Biol. Rep., S.A., No. 3, pp. 1–26. Cape Town.

GILCHRIST, J. D. F., 1918.—*The Eggs and Spawning Habits of the Pilot Fish (Naucrates ductor).* Ann. & Mag. of Nat. His., Ser. 9, II. London.

MARCHAND, J. M., 1934.—*Tagging of Snoek (Thyrsites atun).* MS. Department of Commerce and Industries, Division of Fisheries, Cape Town.

MATTHEWS, J. P., AND B. V. D. DE JAGER, 1951.—*The Development of the Cape Stockfish.* Department of Commerce and Industries, Fisheries and Mar. Biol. Survey Div., Invest. Rep. No. 13, pp. 3–10. Pretoria.

MILLER, D. J., 1952.—*Development through the Prolarval Stage of Artificially Fertilized Eggs of the Pacific Sardine (Sardinops caerulea).* Calif. Fish and Game, Vol. 38, No. 4, pp. 587–594. Sacramento.

ORCUTT, H. G., 1950.—*The Life History of the Starry Flounder Platichthys stellatus (Pallas).* Calif. Div. Fish and Game, Fish. Bull., 78. pp. 1–64. Sacramento.

RYDER, J. A., 1884.—*A Contribution to the Embryography of Osseous Fishes, with Special Reference to the Development of the Cod (Gadus morrhua).* U.S. Com. Fish. Rep., 1882. pp. 455–605. Washington.

EXPLANATION OF PLATES.

Thyrsites atun.

Plate I.

FIG. 1.—Fertilized ovum.
FIG. 2.—Blastodisc. (1 hour).
FIG. 3.—2 cell stage. (2 hours).
FIG. 4.—4 cell stage. (2½ hours).

Plate II.

FIG. 5.—8 cell stage. (3 hours).
FIG. 6.—16 cell stage. (3½ hours).
FIG. 7.—Early blastodermal cap. (6 hours).
FIG. 8.—Blastodermal cap. (11 hours).

Plate III.

FIG. 9.—Segmentation cavity. (13 hours).
FIG. 10.—Germ ring past equatorial position—Blastopore nearing closure. (24 hours).
FIG. 11.—12 somite stage. (27 hours).
FIG. 12.—Advanced stage of embryonic development. (46 hours).

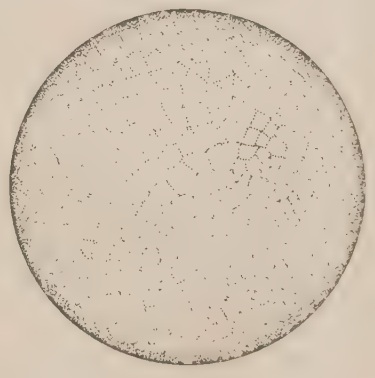
Plate IV.

FIG. 13.—Larva one hour after hatching. 2·1 mm.
FIG. 14.—Larva five hours after hatching.
FIG. 15.—Larva one day after hatching. 2·9 mm.

Plate V.

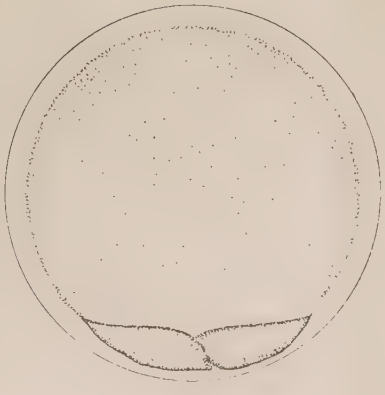
FIG. 16.—Larva two days after hatching. 3·1 mm.
FIG. 17.—Post larva four days after hatching. 3·5 mm.
FIG. 18.—Post larva, nine days after hatching. 3·9 mm.

PLATE 1.



1

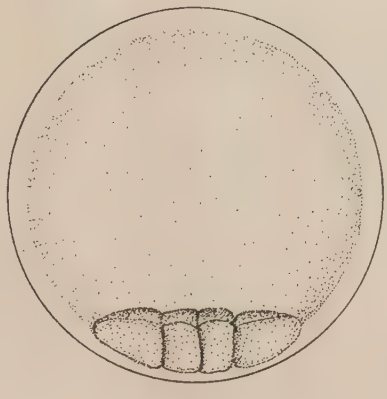
2



3

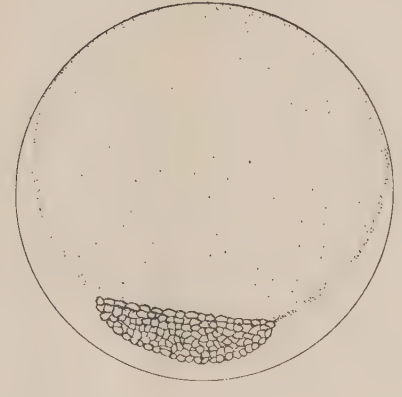
4

PLATE 2.

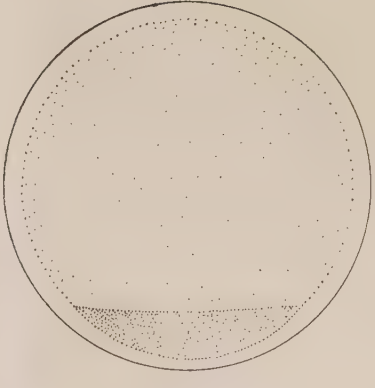


5

6

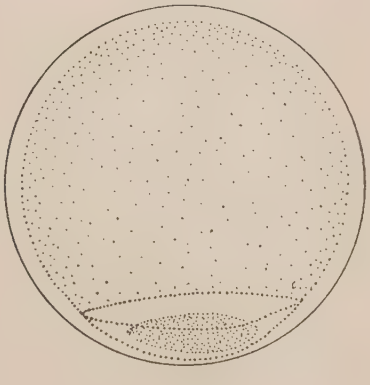


7

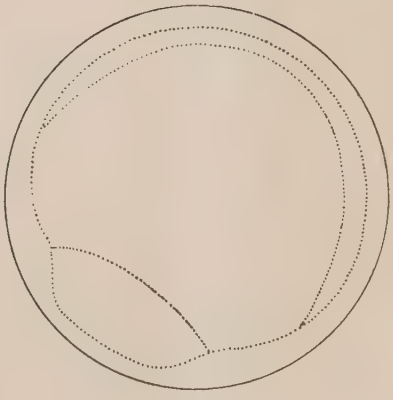


8

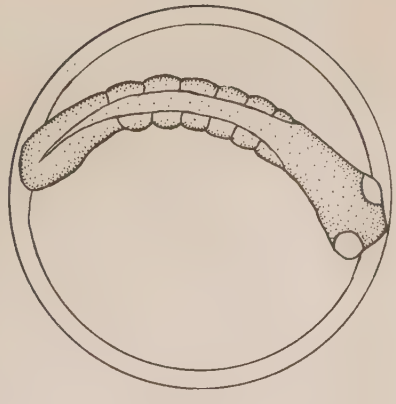
PLATE 3.



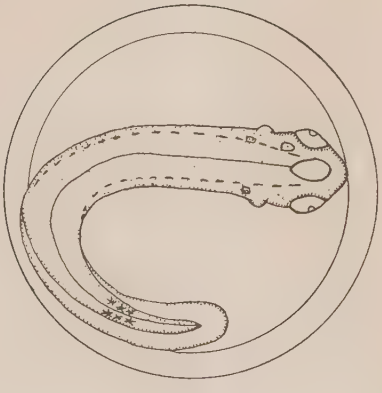
9



10

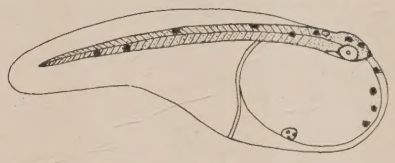


11

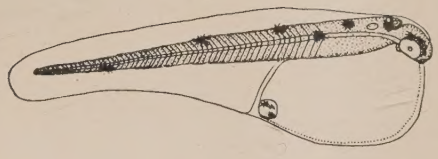


12

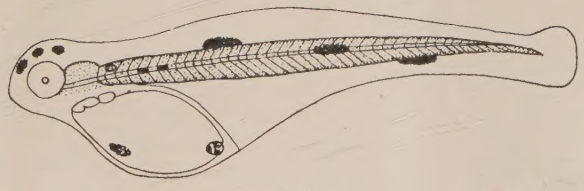
PLATE 4.



13

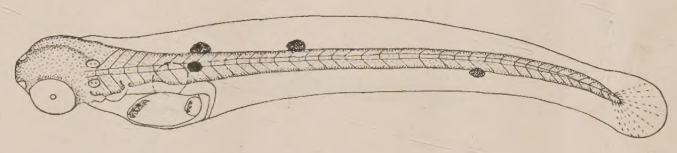


14

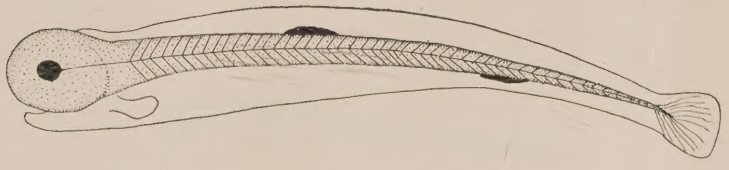


15

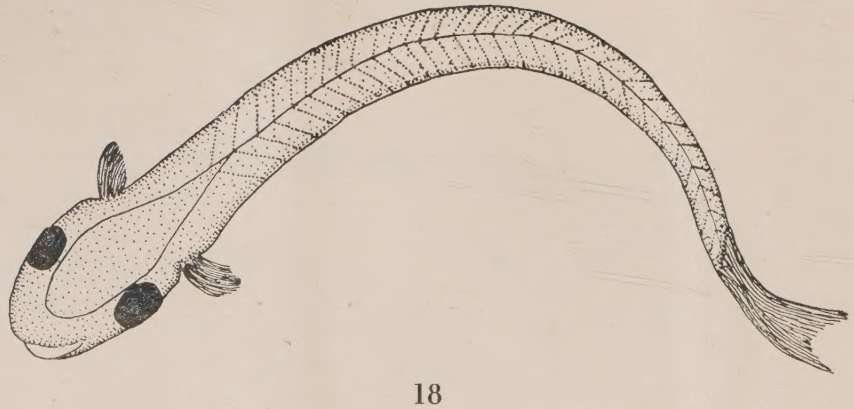
PLATE 5.



16



17



18